Executive Summary

Our country's natural resource challenges today are more complex and more difficult to resolve than ever before. The loss of biodiversity, changing climatic patterns, spread of invasive species, alteration of landscapes, and many other problems pose serious threats to the long-term sustainability of America's natural resources. We urgently need to find new ways to address these problems. In particular, we need new methods and technologies to deal with the scale of the human footprint on the landscape, and new approaches to address the impacts of that footprint. A major challenge is to account for, and ultimately improve, our understanding of the long-term consequences of our actions.

For many important problems now facing resource managers and conservationists, adaptive management is a promising means of facilitating decision making and helping to resolve the uncertainties that hinder effective management. This applications guide builds on the framework of the DOI Adaptive Management Technical Guide (Williams et al. 2007), which describes adaptive management in terms of learning-based management of natural resources. In this guide, we use case studies to show how adaptive management can be used for both management and learning. We focus on practical applications in the areas of importance to DOI managers – climate change, water, energy, and human impacts on the landscape. We present adaptive management as a form of structured decision making, with an emphasis on the value of reducing uncertainty over time in order to improve management. The first half of the guide covers the foundations and challenges of adaptive management, and the second half documents examples that illustrate the components of adaptive management.

Framework of adaptive management

Adaptive management can be useful in cases where natural resources are responsive to management, but there is also uncertainty about the impacts of management interventions. Its origin is rooted in parallel concepts from a variety of perspectives, but in natural resources the term simply means learning by doing, and adapting based on what's learned (Walters and Holling 1990). Applications usually involve dynamic natural resource systems that are subject to only partially predictable environmental variation, along with other sources of uncertainty that limit effective management. The heart of adaptive decision making is the recognition of alternative hypotheses about resource dynamics, and an assessment of these hypotheses with monitoring data. A distinguishing feature is the use of management interventions as experimental treatments, the fundamental goal of which is to improve management.

Implementation issues

Key issues in deciding when to use adaptive management are whether there is substantial uncertainty about the impacts on management, whether it is realistic to expect that we can reduce uncertainty, and whether reducing uncertainty can actually improve management. There is a growing interest in the role of resilience, the potential for surprise, and ways to accommodate these concerns in adaptive decision making.

A key concern is the recognition and measurement of success. An adaptive management project is viewed as successful if progress is made toward achieving management goals through the use of a learning-based (adaptive) decision process. Evaluation of an adaptive management project should involve a comparative assessment that considers the costs of adaptive management above and beyond those that would be incurred in any case. Impediments to the success of adaptive management include, e.g., institutional resistance to acknowledging uncertainty, risk aversion by many managers, myopic management, lack of stakeholder engagement, and other factors.

Learning organizations are critical in implementing adaptive management. For adaptive decision making, many organizations must make a transition from a more traditional "top down" organization structure to one that is more inclusive, collaborative, risk tolerant, and flexible (Gunderson 1999*b*, Stankey et al. 2005). However, an adaptive management approach must comply with statutory and regulatory requirements, most notably the National Environmental Policy Act.

Uncertainty and learning

Four main types of uncertainty are used to characterize the influence of uncertainty on natural resource management in different ways. (*i*) Environmental variation refers to fluctuations in the physical environment, as expressed in precipitation patterns, temperature regimes, etc., which directly and indirectly influence the ecological and physical processes that determine resource dynamics. (*ii*) Partial controllability refers to the difference between the results intended by a given management decision and the results that actually occur. Unintended outcomes are often a result of management decisions implemented by indirect means. (*iii*) Partial observability expresses our inability to observe completely the resource system that is being managed, a nearly universal condition with renewable natural resources. (*iv*) Structural uncertainty expresses a lack of understanding (or lack of agreement) about the processes that control resource dynamics.

Models play a key role in representing uncertainty, by including hypotheses about how a resource system works and how it responds to management. Agreements, disagreements, and uncertainties about resource behaviors can be incorporated in models and used to guide investigations through basic research and learning-oriented management interventions. Uncertainty can be expressed by measures of model credibility, which evolve through time as monitoring data are assessed.

It is becoming increasingly clear that environmental conditions, and the ecological processes influenced by them, are exhibiting directional patterns of change. An obvious example is climate change, in which the environment is seen as evolving directionally in terms of temperature, precipitation and other variables, with associated changes in ecological structures and the processes controlling resource dynamics. It will be increasingly important to account for these patterns in developing management strategies.

Components of the set-up phase of adaptive management

We draw upon our case studies to illustrate the elements and processes of adaptive management in the areas of climate change, water, energy, and human impacts on the landscape. The elements in the set-up phase of adaptive management include: stakeholder involvement, objectives, management alternatives, predictive models, and monitoring protocols.

Stakeholder involvement. Stakeholders bring different perspectives, preferences, and values to decision making. It is important to have at least some stakeholder engagement in all the set-up elements of a project, and to continue that engagement throughout the project. A critical challenge is to find common ground that will promote decision making despite disagreements among stakeholders about what actions to take and why. Failure to engage important stakeholders, and disagreement about how to frame a resource problem and identify its objectives and management alternatives, are common stumbling blocks.

Objectives. Successful implementation of adaptive management depends on a clear statement of project objectives. Objectives represent benchmarks against which to compare the potential effects of different management actions, and serve as measures to evaluate the effectiveness of management strategies.

Management alternatives. Adaptive decision making requires the clear identification of a set of potential alternatives from which to select an action at each decision point. Some actions might affect the resource directly; others might have indirect effects. Learning and decision making both depend on our ability to recognize differences in the consequences of different actions, which in turn offers the possibility of comparing and contrasting them in order to choose the best action.

Predictive models. Models play a critical role in adaptive management, as expressions of our understanding of the resource, as engines of ecological inference, and as indicators of the benefits, costs, and consequences of alternative management strategies. Importantly, they can represent uncertainty (or disagreement) about the resource system. Models are used to characterize resource changes over time, as the resource responds to fluctuating environmental conditions and management actions.

Monitoring protocols. Monitoring provides the information needed for both learning and evaluation of management effectiveness. The value of monitoring in adaptive management is inherited from its contribution to decision making. To make monitoring useful, choices of what ecological attributes to monitor and how to monitor them (frequency, extent, intensity, etc.), must be linked closely to the management situation that motivates the monitoring in the first place, as well as practical limits on staff and funding.

Components of the iterative phase of adaptive management

In the iterative phase of adaptive management, the elements in the set-up phase are folded into a recursive process of decision making, follow-up monitoring, assessment, learning and feedback, and institutional learning. Our case studies are used to illustrate these components in the areas of climate change, water, energy, and human impacts on the landscape.

Decision making. The actual process of adaptive decision making entails decisions at each point in time that reflect the current level of understanding and anticipate the future consequences of decisions. Decision making at each decision point considers management objectives, resource status, and knowledge about consequences of potential actions. Decisions are then implemented by means of management actions on the ground.

Follow-up monitoring. Monitoring provides information to estimate resource status, underpin decision making, and facilitate evaluation and learning after decisions are made. Monitoring is an ongoing activity, conducted according to the protocols developed in the set-up phase.

Assessment. The data produced by monitoring are used along with other information to evaluate management effectiveness, understand resource status, and reduce uncertainty about management effects. Learning is promoted by comparing predictions generated by the models with data-based estimates of actual responses. Monitoring data can also be compared with desired outcomes, in order to evaluate the effectiveness of management and measure its success in attaining management objectives.

Learning and feedback. The understanding gained from monitoring and assessment helps in selecting future management actions. The iterative cycle of decision making, monitoring, and assessment, repeated over the course of a project, leads gradually to a better understanding of resource dynamics and an adjusted management strategy based on what is learned.

Institutional learning. Periodically it is useful to interrupt the technical cycle of decision making, monitoring, assessment, and feedback in order to reconsider project objectives, management alternatives, and other elements of the set-up phase. This reconsideration constitutes an institutional learning cycle that complements, but differs from, the cycle of technical learning. In combination, the two cycles are referred to as “double-loop” learning.

Integrating the components of adaptive management

Four projects are used as case studies to show how all the components are integrated in the application of adaptive management in the field: (*i*) management of river flows at the R.L. Harris Dam on the Tallapoosa River in Alabama; (*ii*) management of horseshoe crabs that provide food resources for migrating red knots in Delaware Bay; (*iii*) management of old-growth pine forests for breeding habitat of the endangered red-cockaded woodpecker; and (*iv*) management of human disturbance near nesting golden eagles in Denali National Park. Each example is comprehensive, in that it includes all the interacting components of adaptive management.

Future directions

As the scope and complexity of resource problems grow, it will be increasingly important to make resource decisions in a structured and transparent way that is based on science and accounts for uncertainty. Because adaptive management meets these conditions, it can be a valuable template for effective decision making by managers in the DOI bureaus. Approaches currently in use in many government agencies "pre-adapt" them to adopting such a framework. For example, all DOI bureaus are engaged in both strategic planning and the tracking of results in plan implementation. Thus, their business practices already involve many of the important elements of adaptive management. A remaining need is to incorporate learning as a fundamental element of strategic planning and implementation, whereby the learning resulting from monitoring and assessment is fed back into future planning. By proactively linking plan implementation to plan development through a learning process, the adaptive cycle of learning-based management is completed and becomes standard business practice.

In recent years there has been steady growth in the engagement of stakeholders in bureau decision making. Active stakeholder engagement helps parties learn from each other, find areas of common ground, and build trust in developing management strategies collaboratively. Such an arrangement offers an incentive to stakeholders to agree on an initial strategy that involves compromise on all sides. In a context of adaptive decision making, negotiations to establish strategies allow parties to be more flexible because they recognize that the outcome of negotiations can be changed as understanding improves and conditions change. In this sense, a key challenge of adaptive management, namely the expression and treatment of uncertainty, can also be one of its strengths.

Two broad focus groups have worked more or less in parallel but independently to develop adaptive management of natural resources. One group focuses on technical issues (models, metrics and propagation of uncertainty, projection of the future consequences of present actions, optimal decision making in the face of uncertainty). The other group focuses on collaboration (institutions, stakeholders, cooperative interactions, elicitation of stakeholder values and perspectives). For the most part, researchers, practitioners, and even organizations tend to emphasize either one thrust or the other. The challenge is ultimately to join the two in a more unified vision and process, in which each reinforces and strengthens the other.

Opportunities for collaboration between adaptive management and emerging important fields of investigation are obvious. The developing field of ecosystem services can contribute to a framework for evaluating management impacts on the quantity and value of services provided by ecosystem attributes and processes. Resilience, vulnerability, and risk all have important roles in adaptive decision making, and their linkages need further examination and development. In particular, adaptive decision making has to be flexible and resilient enough to respond to the inevitable surprises that arise in resource management, because only then can ecosystems and their values be dependably maintained in the future.

Appendix of case study overviews

The appendix contains paragraph-length thumbnail sketches of adaptive management projects used as examples in this guide. They range from translocation of endangered ducks in the Hawaiian islands, to restoration of Great Plains prairie potholes and New England shrub communities, to management of wetlands as waterbird habitat, to siting of renewable energy projects.